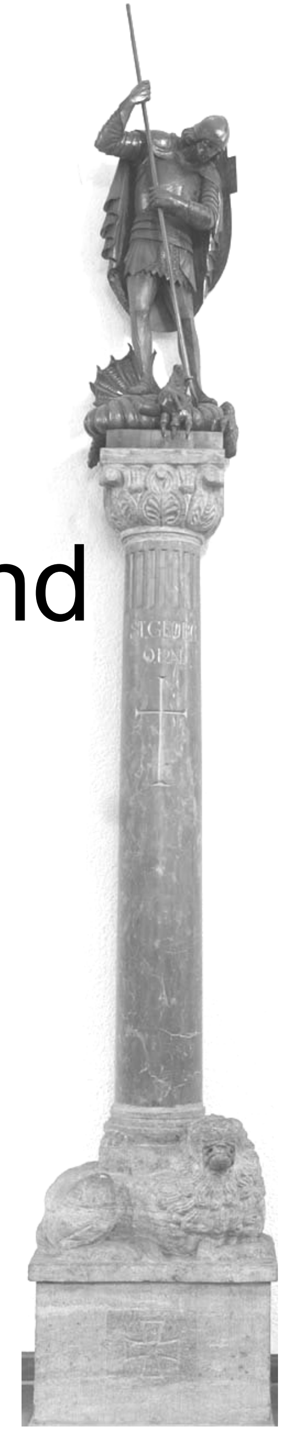
A Recoil Separator Underground



Manoël Couder – Daniel Schürmann

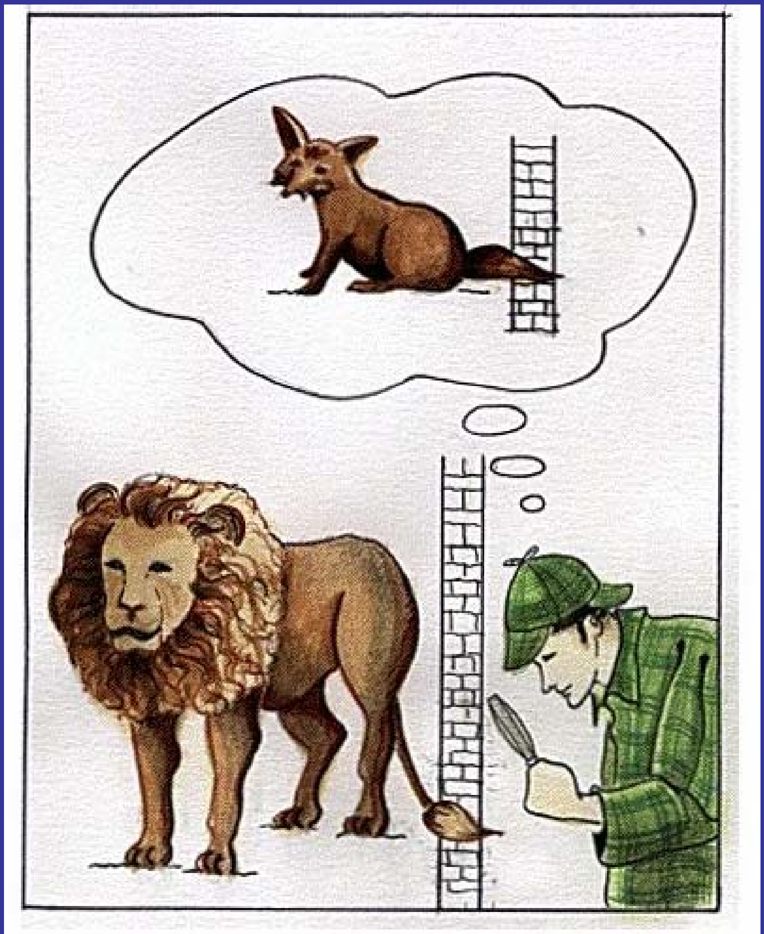
University of Notre Dame

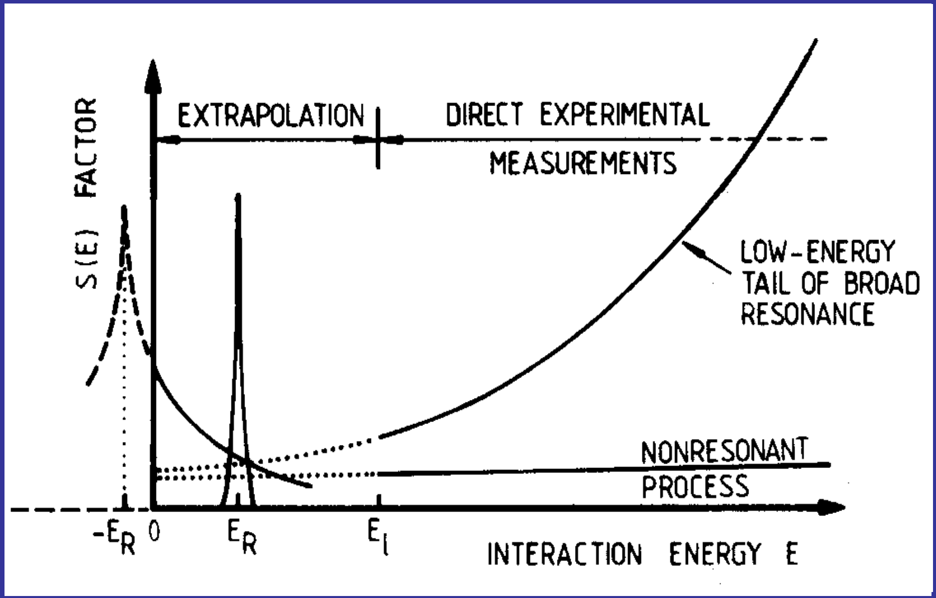
Joint Institute for Nuclear Astrophysics

J I N A

I S N A P

but…





sometimes extrapolation fails !!

From: Claus Rolfs

Low energy cross section challenge

Effort to extract the γ signal at low energy (fight against background) is needed because cross section drops exponentially:

Increase the number of interactions:

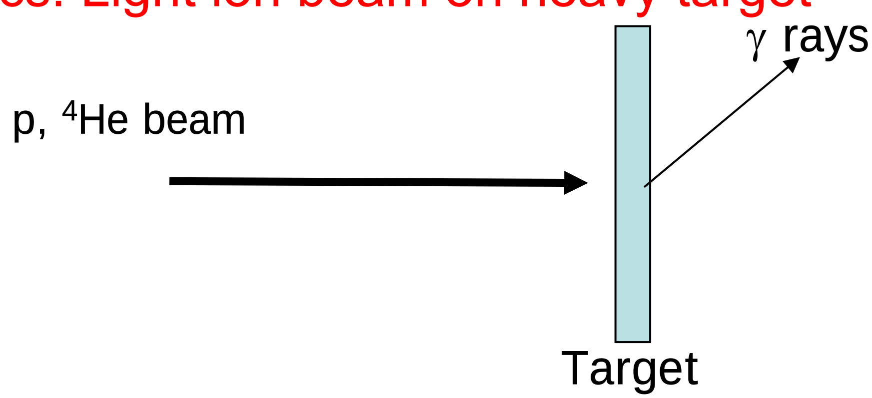
- High intensity beam
- High density target

Improved detection techniques

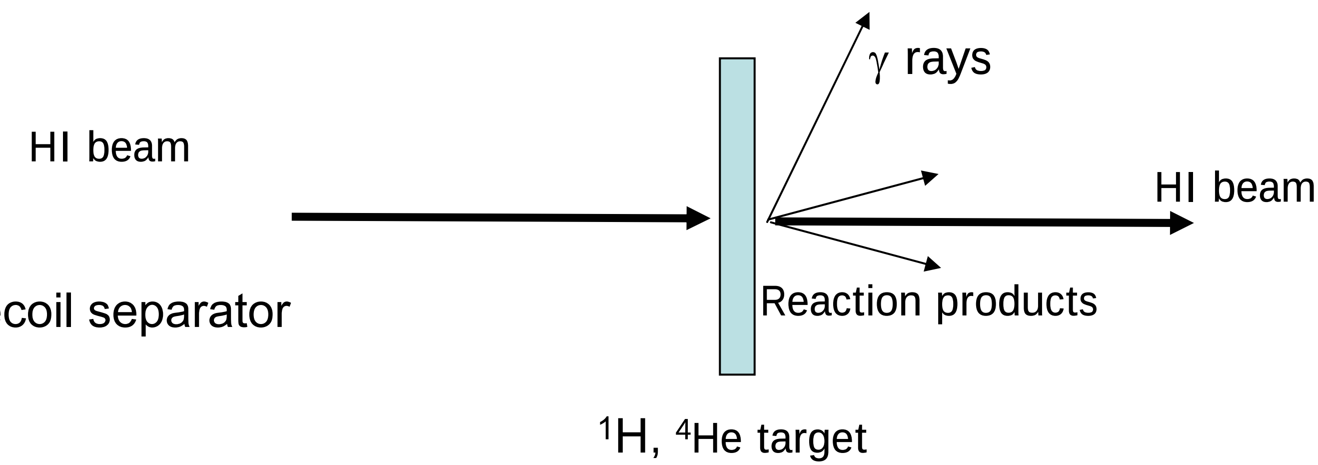
- Improved detection techniques
  - γ coincidence (Q value gate)
  - Active shielding
  - Tracking in γ-ray detector (GRETINA/GRETA/AGATA)
- Underground lab

Find additional tags to improve detection for (p,γ) and (α,γ)

Direct kinematics: Light ion beam on heavy target



Inverse kinematics: "Heavy ion" beam on light target



Need a recoil separator

ALNA

Accelerator Laboratory for Nuclear Astrophysics underground

Systematic study of reactions relevant for the understanding of Helium burning in red giant and AGB stars towards the low energy range

Phase 1:

direct kinematics ^{1}H and ^{4}He (accelerator 1 MeV)

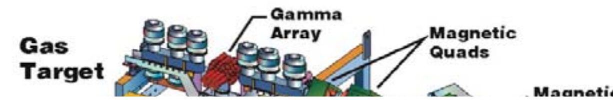
Phase 2:

Inverse kinematics + a recoil separator coupled to a 1 MeV/u accelerator (RFQ/LINAC or Tandetron/Pelletron)

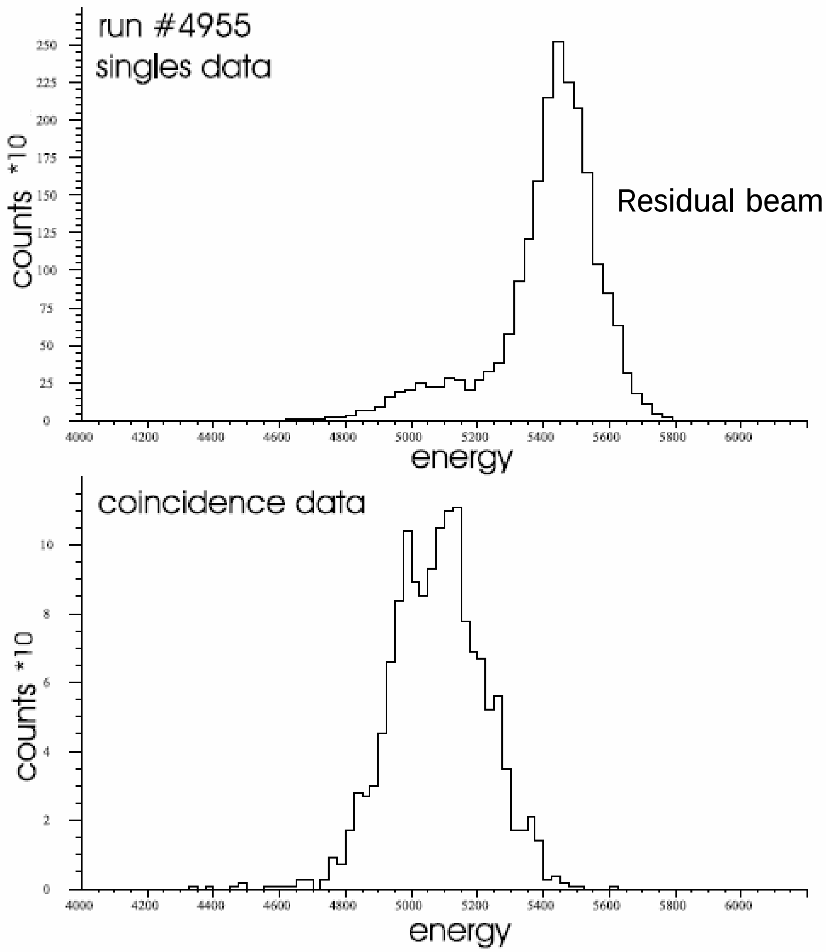
Existing device

- Successful recoil separator are currently in use
  - Daresbury recoil separator @ HRIBF – Oak Ridge
  - DRAGON @ TRIUMF dedicated to radiative capture induced by radioactive beams
  - ERNA @ Bochum/Germany designed for $^{12}C(\alpha,\gamma)^{16}O$

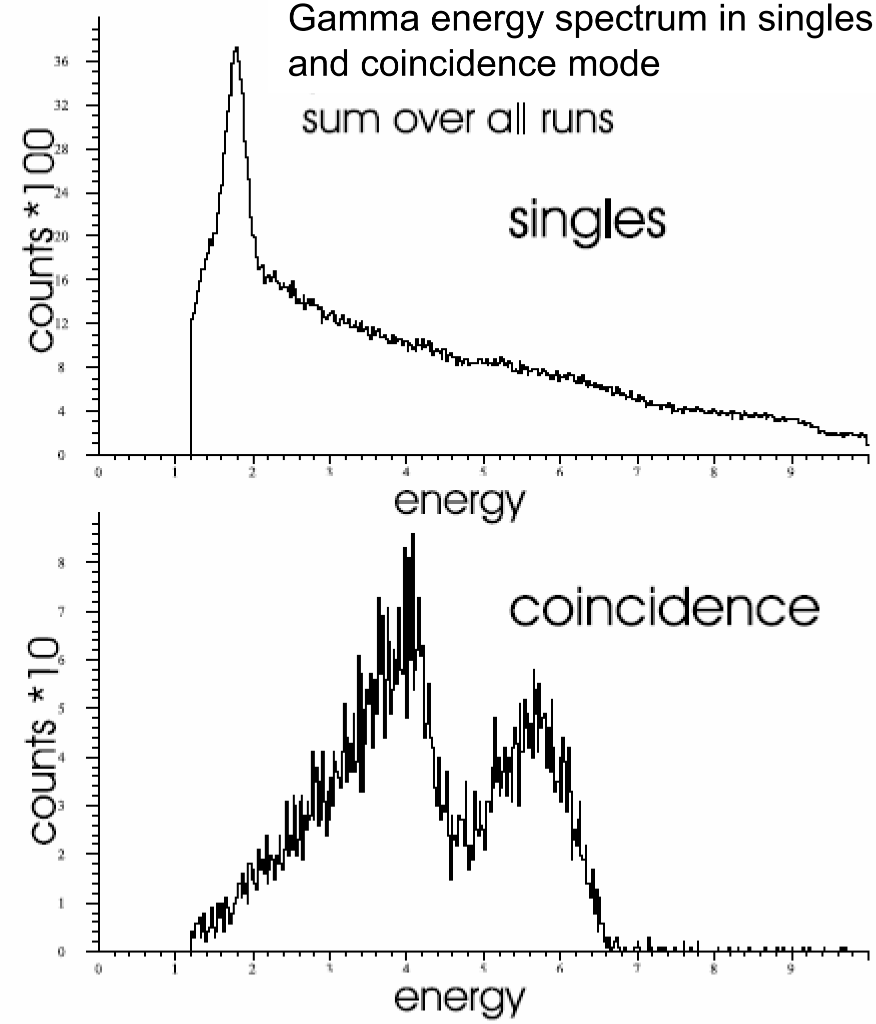
DRAGON @ Triumf



Recoil energy spectra in singles and coincidence mode for $^{21}Ne(p,\gamma)^{22}Na$ at Ecm = 258.6 keV

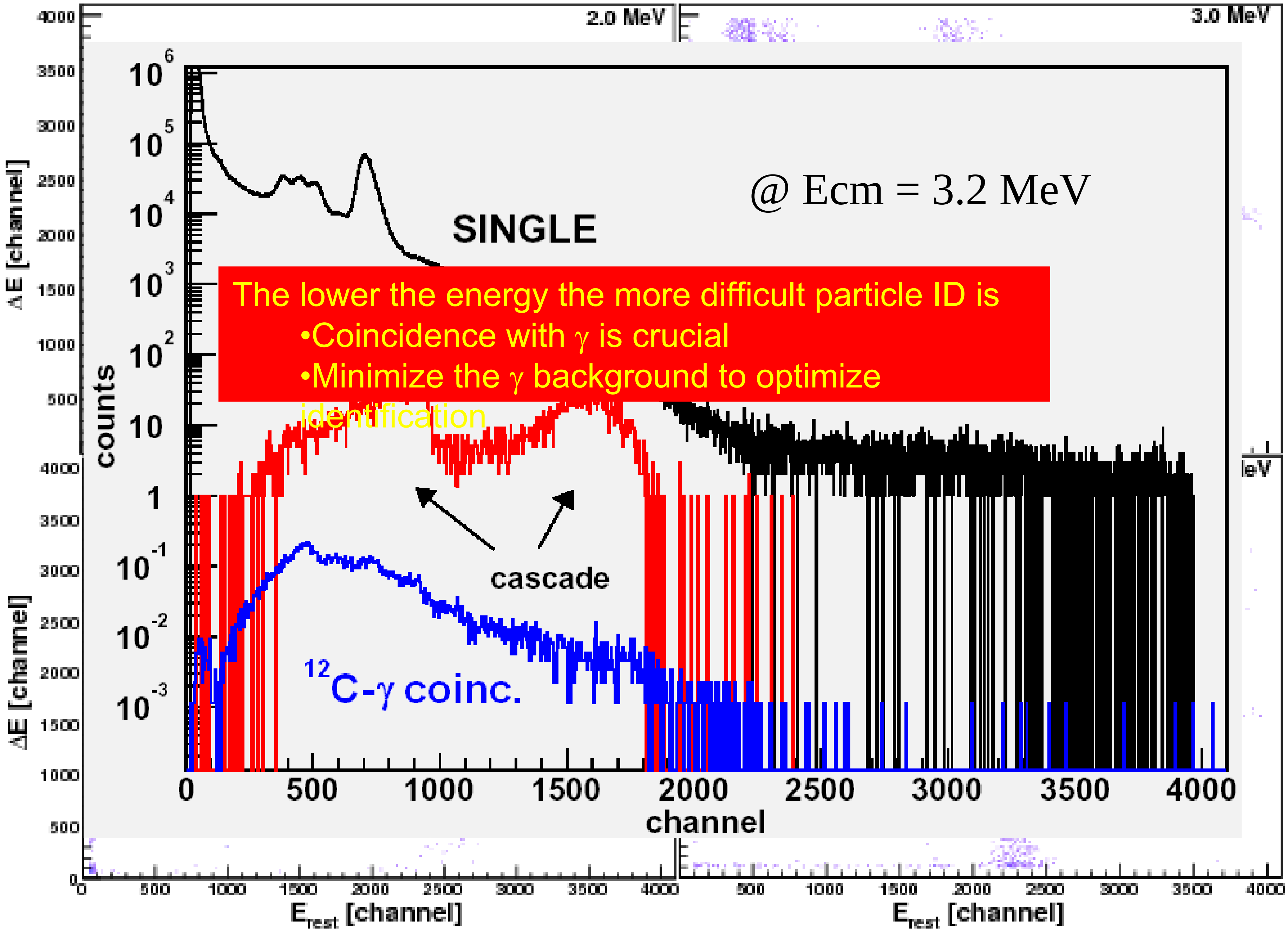


Gamma energy spectrum in singles and coincidence mode



Spectrum and picture from S. Engels Thesis, http://dragon.triumf.ca/docs/sabine_thesis.pdf

ERNA: $^{12}C(\alpha,\gamma)^{16}O$



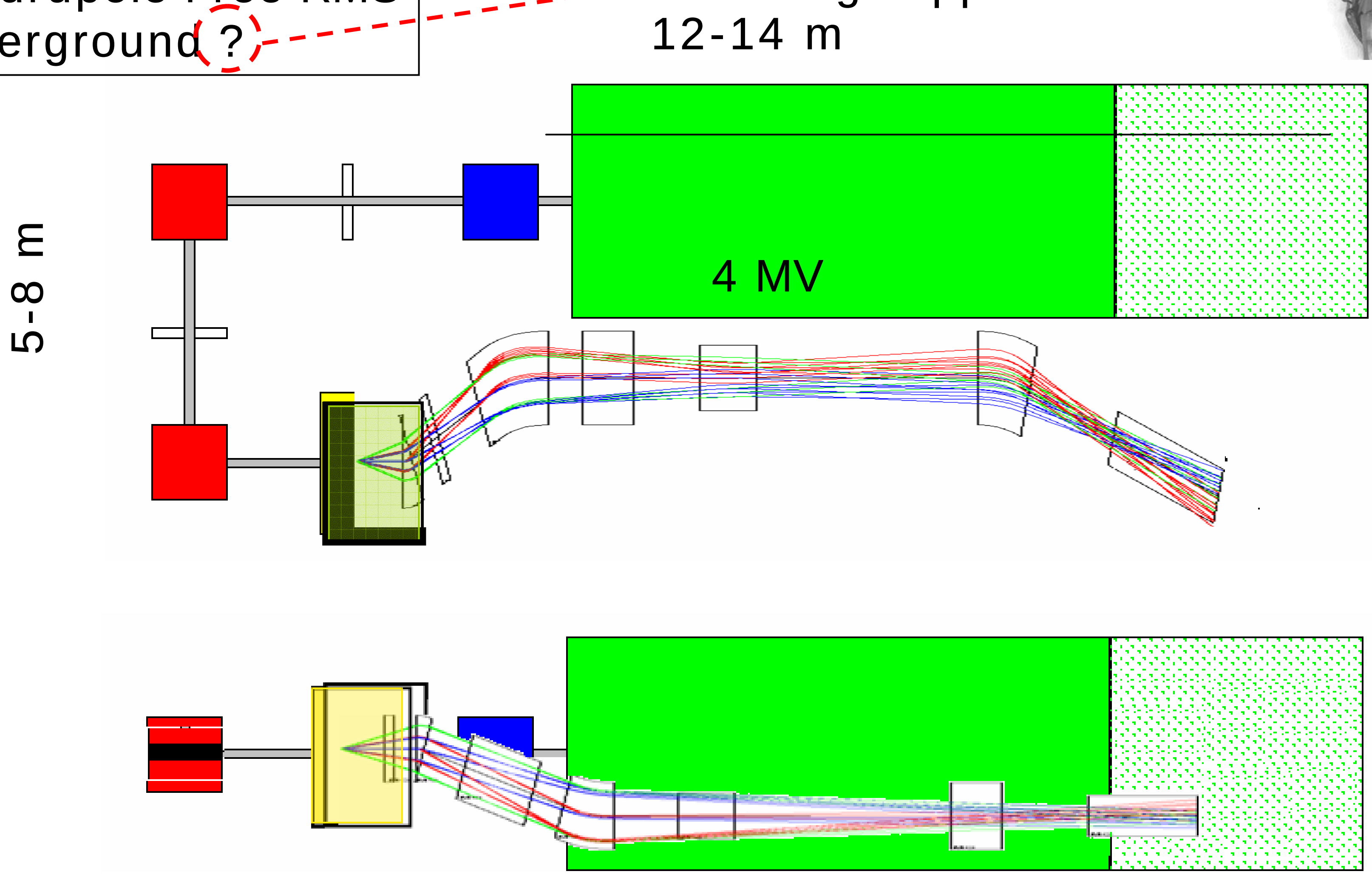
The lower the energy the more difficult particle ID is

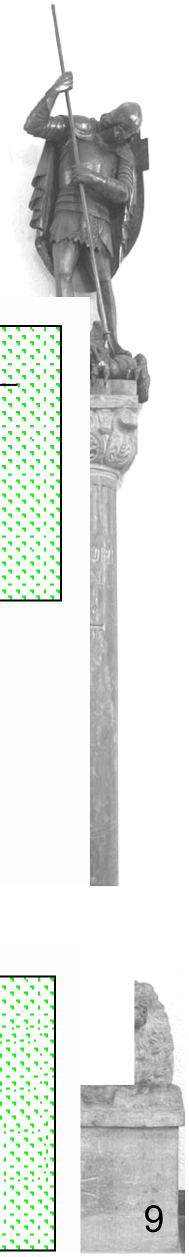
- Coincidence with γ is crucial
- Minimize the γ background to optimize identification

Design by Lucio Gialanella from Naples

Possible layout:
-Single stage (3.5 MV)
-ECR source
-Quadrupole Free RMS
-Underground ?

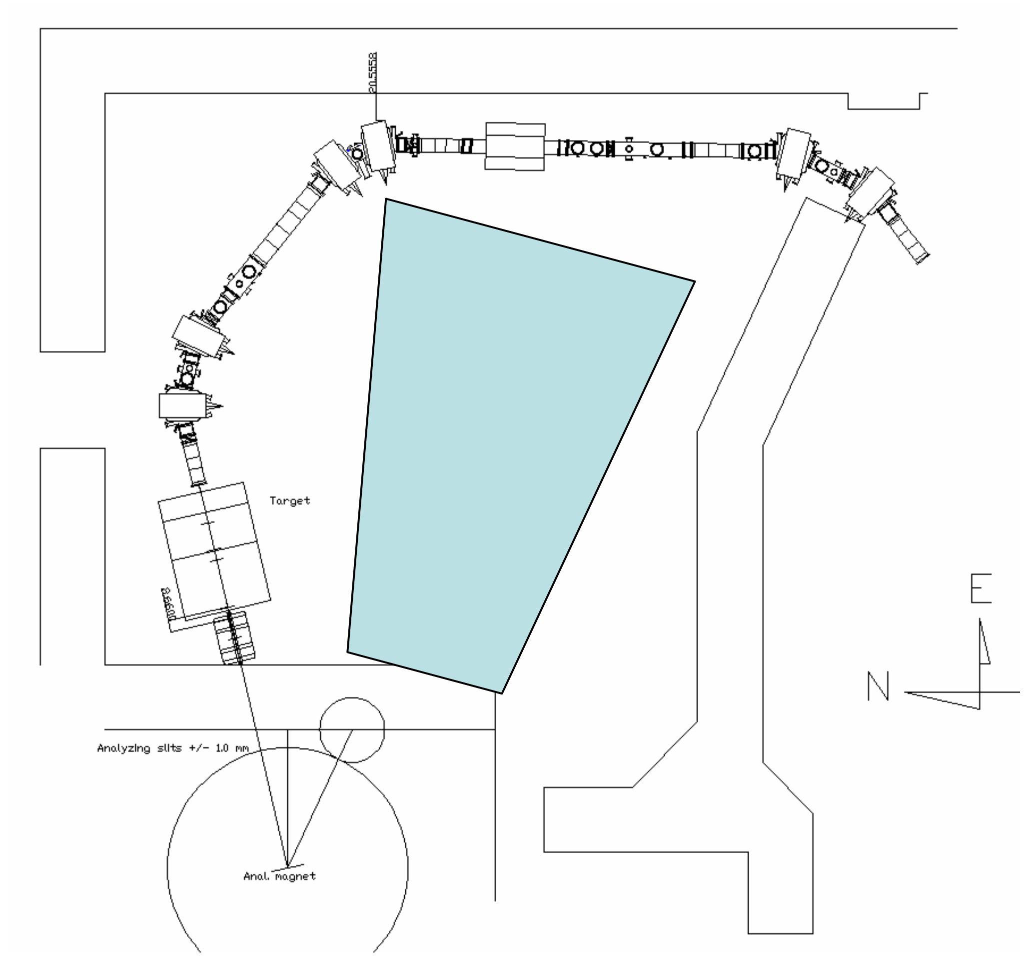
Angular acceptance = 50 mrad
Energy acceptance= ±15%
Beam suppression = $10^{-?}$
Gamma bkg suppr = 10^3-10^5





St. George

STrong Gradient Electro-magnetic Online Recoil separator for capture Gamma ray Experiments



KN accelerator

St. George: Design parameters

Stable beam from the KN (4MV) Van de Graaff accelerator

Beam intensity up to 100 μA (~10^{15} pps)

Beam mass < ~40

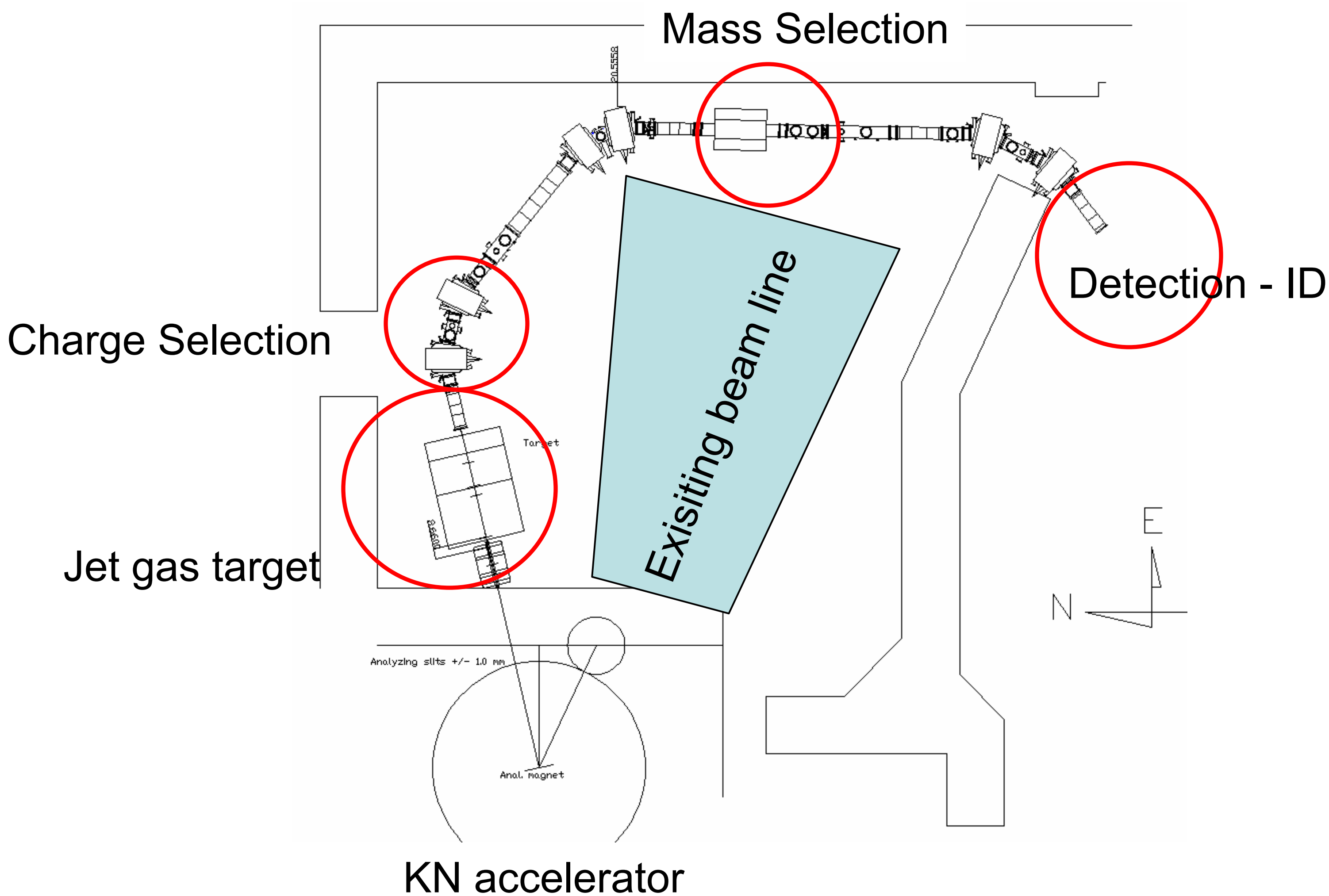
Acceptance

Reaction	E_{CM} E_{beam}	$\Delta E/E$ (%)	θ (mrad) (deg)
$^{18}O(\alpha,\gamma)^{22}Ne$	360 keV 2. MeV	7.4%	40 mrad 2.3 deg.
$^{22}Ne(\alpha,\gamma)^{26}Mg$	460 keV 3. MeV	6.5 %	32 mrad 1.8 deg.
$^{36}Ar(\alpha,\gamma)^{40}Ca$	1.25 MeV 12.5 MeV	1.8 %	9 mrad 0.97 deg.

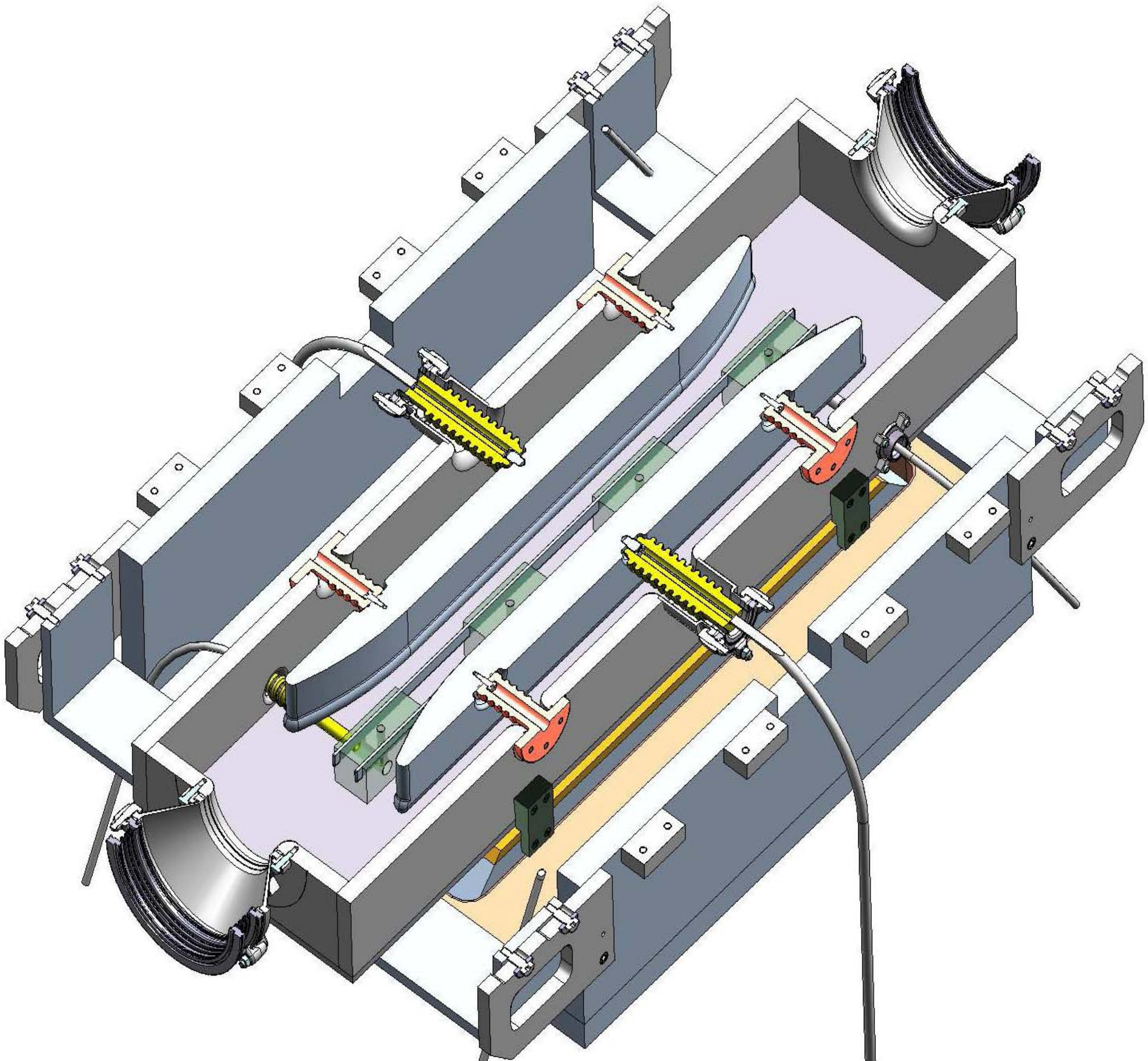
Sample of the list of reactions

St. George

STrong Gradient Electro-magnetic Online Recoil separator for capture Gamma ray Experiments

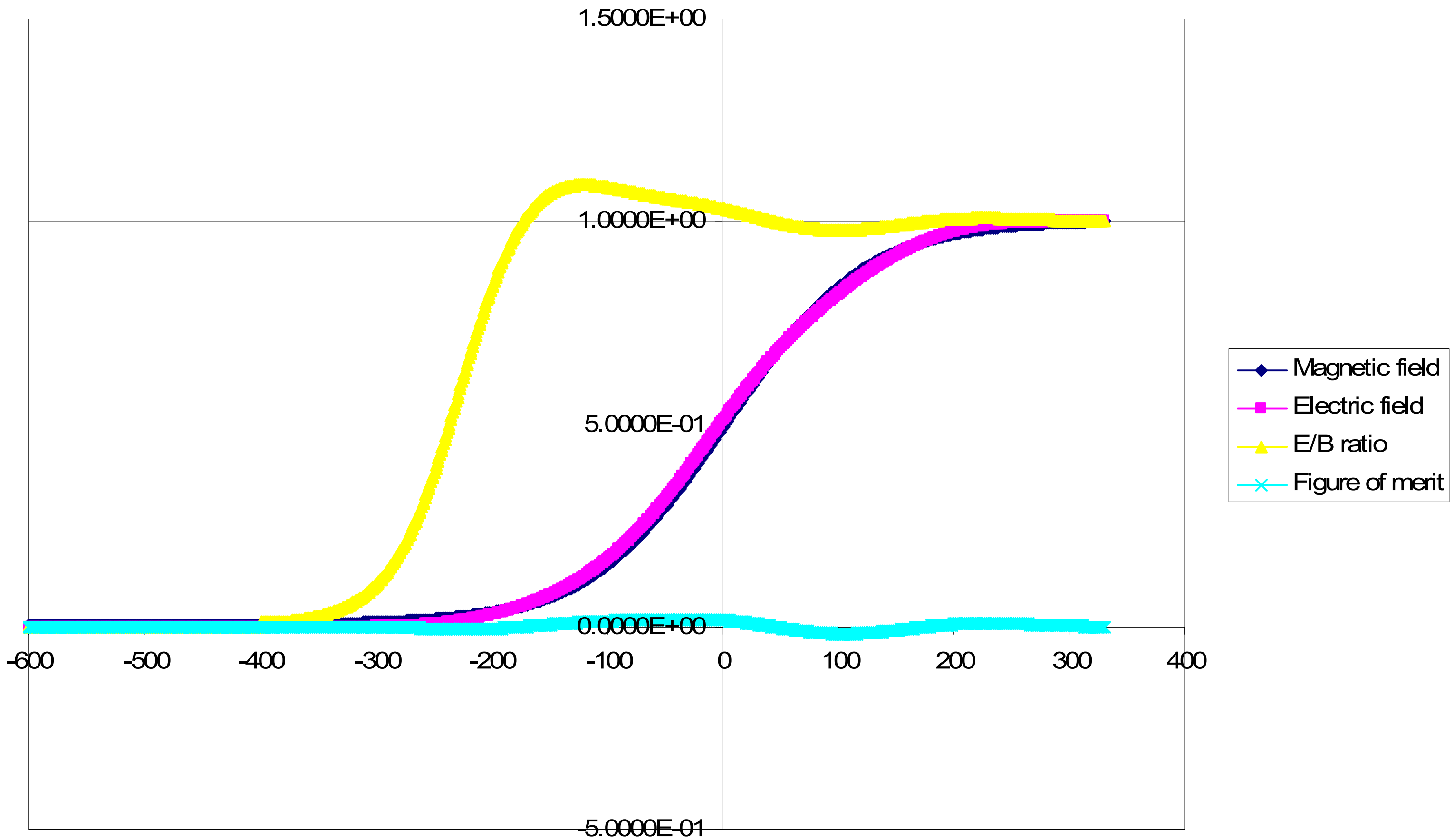


Mass selection: Optimized Wien filter

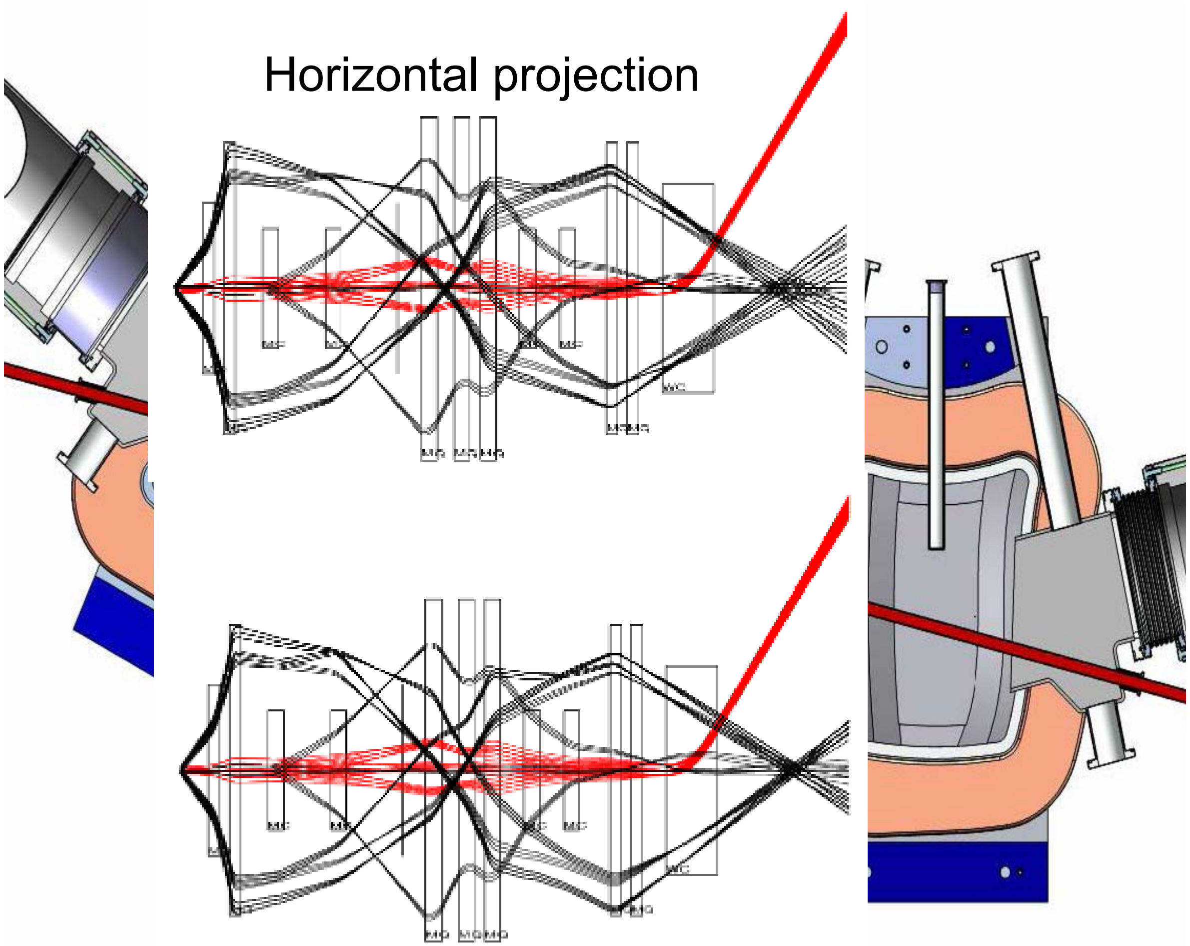


Wien filter fringe fields - longitudinal

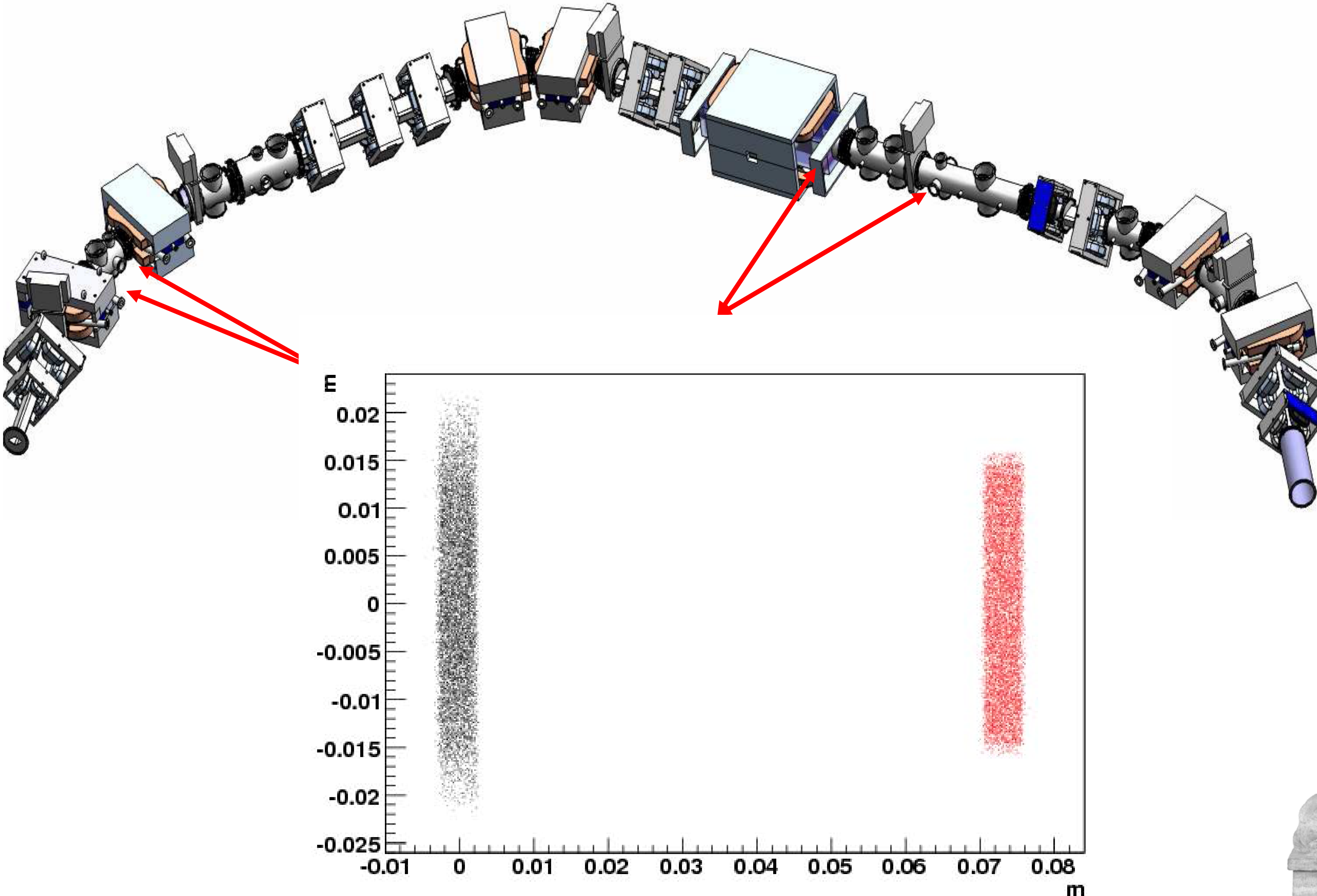
Modified Wien filter fringe field



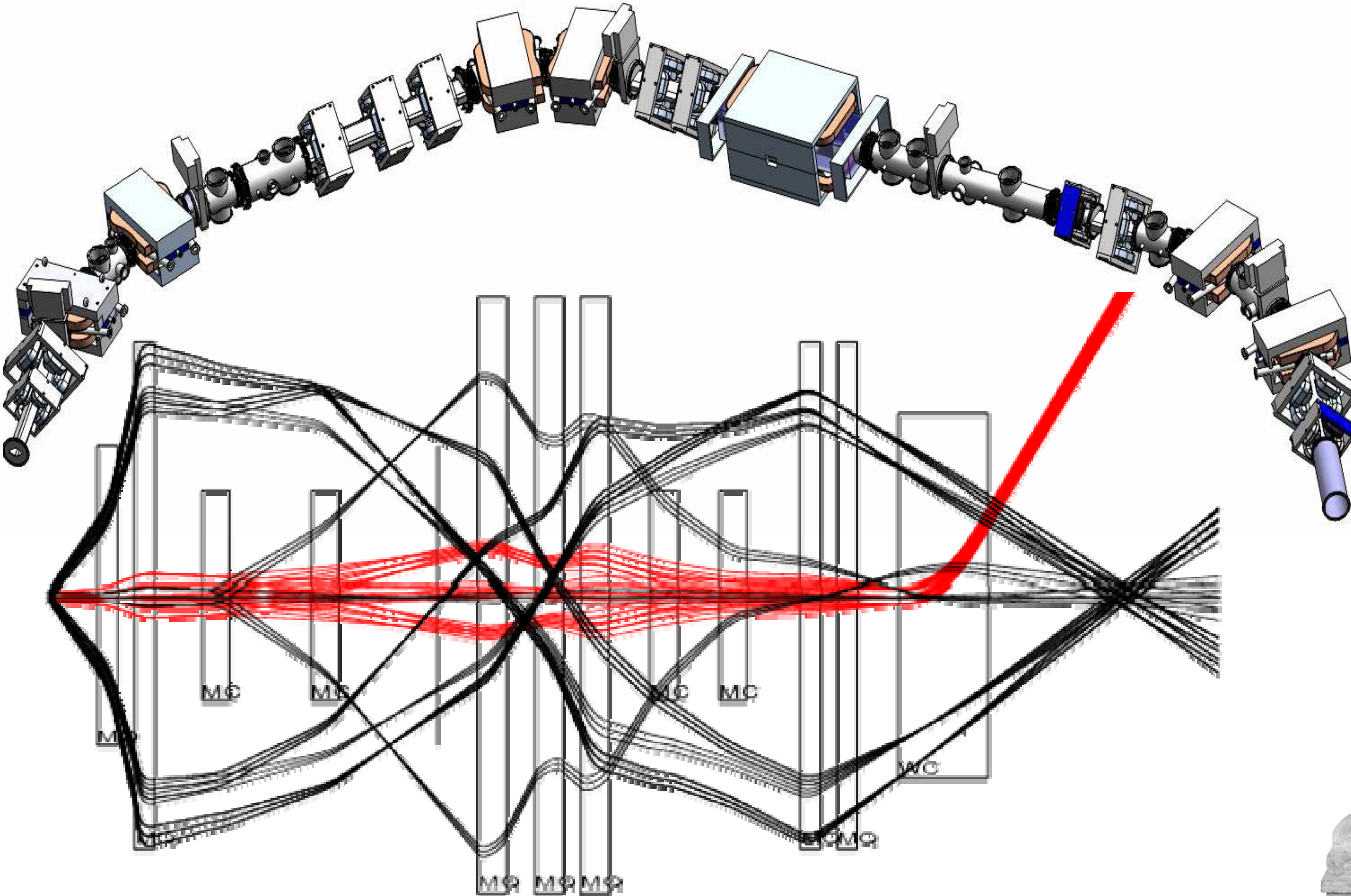
Aberration correction



$^{24}Mg(\alpha,\gamma)^{28}Si^{5+}$ @ 8 MeV



$^{18}O(\alpha,\gamma)^{22}Ne^{3+}$ @ 2. MeV



Lesson learned from design

- The lower the energy the larger the acceptance of the recoil separator →
  - – Beam rejection more difficult to obtain
  - – Large magnets
  - – Large aberration

DEVELOPMENT TAKES TIME

Status and perspective

St. George:

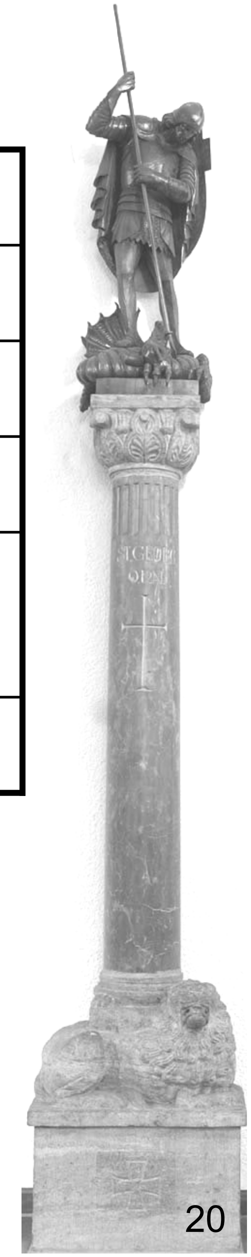
- Elements ordered with Bruker Biospin
- Charge state distribution/Energy loss through gas target have to be studied
- We should start commissioning fall of 2008

Future underground:

- Design should start as soon as possible

Space requirements

Depth	>3000 m.w.e
Space for accelerator	15*10*5 m^3
Space for beam line 1st phase	15*10*5 m^3
Space for RMS 2nd phase	15*20*5 m^3
Space for additional system (e.g. SF_6 storage tank)	8*8*5 m^3
Space for control-acquisition	8*8*5 m^3



Requirements

Electrical power phase 1	100 kW
Electrical power phase 2	200 kW
Hazardous material:	High pressure gas (SF_6), Cryogens, Hydrogen target

- Crane for accelerator and target room
- Ventilation/air conditioned room/ stable temperature
- Small shop
- Liquid Nitrogen
- De-ionized water